Li-ion Tamer®

Advancements in Energy Storage Safety through Smarter Sensing

Presented to Energy Storage Safety & Reliability Forum

March 4th, 2020
What is Li-ion Tamer?

- Safety product
- For lithium-ion batteries
- Detects off-gas events
- Earliest warning
- Avoid catastrophic events
- 10 years of R&D
- www.li-iontamer.com
Who is Li-ion Tamer?

- Nexceris founded in Columbus, OH
- Developed H₂ sensing platform
- US Navy ASDS Li-ion Battery Fire
- Phase I SBIR for off-gas monitoring technology
- DOE ARPA-E AMPED project
- Phase II SBIR for off-gas monitoring technology
- US Navy Rapid Innovation Fund (Phase III SBIR)
- Highlighted as success story at ARPA-e’s Energy Innovation Summit
- Received GameChanger technology award from Connected Plant
- Announcement of partnership with Honeywell and Xtralis

Timeline:

1994: Nexceris founded in Columbus, OH
2006: Developed H₂ sensing platform
2008: US Navy ASDS Li-ion Battery Fire
2010: Phase I SBIR for off-gas monitoring technology
2012: DOE ARPA-E AMPED project
2015: Phase II SBIR for off-gas monitoring technology
2017: US Navy Rapid Innovation Fund (Phase III SBIR)
2018: Highlighted as success story at ARPA-e’s Energy Innovation Summit
2019: Received GameChanger technology award from Connected Plant
2020: Announcement of partnership with Honeywell and Xtralis
Anatomy of a battery failure

Battery Failure Stages

• **Stage 1: Abuse factor**
  - Thermal, electrical, or mechanical abuse

• **Stage 2: Off-gas generation**
  - Occurs regardless of cell form-factor

• **Stage 3: Smoke generation**
  - Catastrophic failure is imminent

• **Stage 4: Fire generation**
  - Likelihood of propagation drastically increases
Regions of battery failure

- Battery Abuse
  - Propagation
  - Cell Damage
- Fire
  - Ignition
- Off-gas
  - Heat Release
- Smoke
Battery Failure (overcharge)

Test #1 conditions
• Third-party data (DNV-GL)
• 100% SOC, constrained
• Overcharged at 50A (0.8C)
• 63 Ah Pouch Cell Type
• FTIR data gathered during failure (plus H₂ and LEL monitors)

Remarks
• Low-level off-gassing occurs early, prior to thermal runaway

Thermal runaway: $T_{\text{surface}} > 1000^\circ \text{C}$
Battery Failure (overcharge)

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- Low-level off-gassing occurs early, prior to thermal runaway
- H₂, HCl, and HF generated during thermal runaway
- LEL monitor does not alarm
Battery Failure (overcharge)

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- H₂, HCl, and HF generated during thermal runaway
- LEL monitor does not alarm
- Li-ion Tamer correlates to first FTIR off-gas signatures

Li-ion Tamer provides 6.4 minutes of early warning prior to thermal runaway
Battery Failure (overcharge mitigation)

**Test #2 conditions**

- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- Charge is stopped at Li-ion Tamer indication
Battery Failure (overcharge mitigation)

Test #2 conditions
• Third-party data (DNV-GL)
• 100% SOC, constrained
• Overcharged at 50A (0.8C)
• 63 Ah Pouch Cell Type
• Charge is stopped at Li-ion Tamer indication

Remarks
• Li-ion Tamer correlates to first FTIR off-gas signatures
• Thermal runaway of cell is avoided by removing charge at Li-ion Tamer indication

Li-ion Tamer Prevents Thermal Runaway

![Graph showing FTIR Absorption Units over time with Li-ion Tamer signal](image)
“The Li-ion Tamer® sensor indicates only seconds after off-gassing occurs. In addition, testing was performed where a cell was being overcharged and charging stopped when off-gas was released as indicated by the Li-ion Tamer. The cell temperature ceased to increase, and off-gassing started to decline until the cell was considered stable. Thus, demonstrating it is feasible to ‘pull back’ a cell after it has begun off-gassing, but before thermal runaway occurs.”

- DNV-GL Maritime Advisory Group
Compiled Failure Data (thermal abuse)

<table>
<thead>
<tr>
<th></th>
<th>100% SOC</th>
<th>30% SOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>5°C/min</td>
<td>10.8 min</td>
<td>16.8 min</td>
</tr>
<tr>
<td>30°C/min</td>
<td>2.3 min</td>
<td>3.0 min</td>
</tr>
</tbody>
</table>

Minutes between cell venting and thermal runaway

30°C/min

5°C/min

0  5  10  15  20
## Compiled Failure Data (electrical abuse)

<table>
<thead>
<tr>
<th>Charge rate</th>
<th>Mean off-gas early warning (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5C</td>
<td>2.9</td>
</tr>
<tr>
<td>3C</td>
<td>8.3</td>
</tr>
<tr>
<td>1C</td>
<td>12.3</td>
</tr>
</tbody>
</table>

**Diagram:**

- **5C**
- **3C**
- **1C**

**Minutes between cell venting and thermal runaway**

- 0
- 5
- 10
- 15
- 20
Off-gas event video
Thermal runaway videos
Delivering single cell fault detection to our customers so they can be aware of the earliest sign of failure, enabling the option to prevent thermal runaway.
Applications Engineering

Li-ion Tamer Application Engineers

- Outside air penetration points
- Air exchange rate
- Battery rack layout
- System constraints
- Possible mitigating actions
- Battery rack design

Customer system specific Li-ion Tamer design
Li-ion Tamer Stats

- 75 Projects (411 MWHR)
- 4,621,176 Cumulative Sensor Hours
- 1,135 MWHR Pipeline Projects
- 0 Battery Fire Occurred in Systems with Li-Ion Tamer
### Product Benefits

- **Early warning** of lithium-ion battery failures
  - Average of 10-minute early warning based on experimental results (100+ battery failures)

- **Prevent thermal runaway** with proper mitigating action
  - If abuse factor is stopped early, failure can be altogether prevented

- **Single cell failure detection** without electrical or mechanical contact of cells
  - Easy installation and localized monitoring enables detection at the earliest sign

- **Calibration-free** product
  - Innovative machine learning algorithms create maintenance-free product

- **Auto diagnostic** capabilities
  - System will automatically diagnose any sensors that are malfunctioning

- **Extended lifetime**
  - Sensors have extended lifetime that exceeds lithium-ion battery systems (15+ years)

- **Reduction/removal of false positives**
  - Network of reference sensors removes possibility of false positive alarms
Protect your people, property and brand with Li-ion Tamer

www.li-iontamer.com